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Minding gaps on the skin: opposite bisection biases on forehead and back of one's head

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Abstract

Humans perceive the world from an egocentric perspective, while being able to mentally take a third person's perspective. Graphesthesia tasks revealed that letters written on the back of one's own head are consistently perceived from an embodied perspective, while the perspective on one's front is less consistent and often disembodied. We developed a cutaneous gap bisection task as a more discrete measure of the perspective on the body. In analogy to a visual pseudoneglect, we expected bisections to deviate towards the left ear when perceived from an embodied perspective. While this hypothesis was confirmed for gap bisections on the back, the results on the front suggest overall a disembodied perspective. Contrary to our expectation, this pattern was not predicted by the spontaneous perspective participants took in a graphesthesia task, indicating different cognitive mechanisms. We discuss these findings in the frame of the current literature on spatial attention and perspective taking.

Keywords: Perspective, embodiment, line bisection, cutaneous perception, body space, pseudoneglect, visual-somatosensory interactions

1. Introduction

A central aspect of human *self-consciousness* is our stable embodied first person perspective on the world (e.g. Blanke, 2012). In contrast, a central aspect of human *social life* is the ability to mentally simulate another person's perspective (e.g. Costantini, Committeri, & Sinigaglia, 2011) albeit it is hotly debated to what extent such process is automatic or rather effortful (e.g. Arnold, Spence, & Auvray, 2016; Cole, Atkinson, Le, & Smith, 2016)). Such dyadic perspective exists not only for the space around us, but also for our own body and self, linked to the perception of the self as a subject ("I") or as an object ("me").

One task that has widely been used to investigate the spontanous perspective on one's own body surface is a graphesthesia task (Natsoulas & Dubanoski, 1964), in which letters or numbers are drawn on body parts of a blindfolded participant, who is required to identify the orientation of the stimulus. During this task the letter "b" drawn by an experimenter on the front, for example, can either be perceived as a "d" (embodied perspective) or as a "b" (disembodied perspective). An early, but thorough investigation by Stracke (1947) suggested that signs drawn on the back are perceived as they are drawn by the experimenter (i.e. from an embodied perspective), while those on the front are rather perceived as mirror-inverted, i.e. as if the participant "looked" through the head on the number ("frontal plane hypothesis" (Duke, 1966)), suggesting an embodied perspective as well. Yet, already Stracke (1947) noticed that participants were slower and less consistent in their responses for drawings on the front than an on the back. And while the results on the back of the head are consistent across subjects and studies (Duke, 1966; Parsons, 1987; Stracke, 1947), the results on front stimulation are much less consistent and have been shown to depend for example on the participant's gender (Duke, 1966), body posture (Stracke, 1947), on the currently available vestibular input (Ferrè, Lopez, & Haggard, 2014) and, in a slight task modification, on the participant’s momentary self-focus (Hass, 1984).

This suggests that in graphesthetic perception on body parts with which we typically face other people in social interactions (i.e. front face), we more readily take the observer’s perspective, while both situational and inter-personal aspects might play a role to what extent we spontaneously do so. There are, however, two important limitations to this often-used task: first, the participant's responses allow only a dichotomous classification into perception as mirror-inversed (embodied perspective) or not (disembodied perspective), not allowing for any intermediate state. Second, the task involves writing and reading, which is a special situation that strongly involves communicative and social aspects, which are mostly not controlled for (see e.g. Arnold et al., 2016; Hass, 1984 for exceptions). Participants might thus more or less explicitly take into account the experimenter's perspective to solve the task. Here, we used an alternative, purely spatial task with a continuous measure to investigate the perspective on the own body. We used a *cutaneous gap bisection task* on healthy participants' front and back, which required them to bisect the empty space between two endpoints of a line (Bradshaw et al. 1986).

In the visual domain, it has been shown that in healthy, right-handed participants, bisections of a visible line from a first person perspective are slightly, but consistently shifted towards the left of the objective midpoint, a phenomenon termed "pseudoneglect" (Bowers & Heilman, 1980). Bisecting the empty space between two visually presented endpoints of a line ("gap bisection") leads to similar, albeit smaller (left-sided) lateral displacements (Bradshaw, Bradshaw, Nathan, Nettleton, & Wilson, 1986; McIntosh, McClements, Dijkerman, & Milner, 2004). Whether a comparable peseudoneglect exists in the tactile domain as well (bisection of felt distances on the skin) has been studied much less systematically. Some previous investigations described a leftward shift of the subjective meridian when participants were asked to point to the body midline (Richard, Honoré, & Rousseaux, 2000; Spidalieri & Sgolastra, 1997). Spidalieri and Sgolastra (1999) found a leftward displacement of the anterior head midline, yet they did not test midline pointing on the back of the head. A proper characterization of pseudoneglect in the somatosensory modality has, however, never been provided, and was one of the aims of the present study.

We investigated healthy subjects' pointing biases to the spot laying halfway between two touch stimuli applied simultaneously to either the forehead or, in separate trials, to the back of the head. We generally assumed an existence of a pseudoneglect in the somatosensory modality. Thus, we predicted a leftward deviation relative to the actual midpoint on the back (i.e. a pseudoneglect from an embodied perspective, see Figure 1). For the front we predicted that participants using spontaneously a disembodied perspective in a graphesthesia task, which requires writing letters on one's forehead (Shimojo et al., 1989; Hass, 1984), would show a *right*ward bias, while those using an embodied perspective should also show a *left*wards bias.

2. Methods

2.1 Participants

The 40 subjects (20 women) had a mean age of 37.5 years (SD = 6.2 years) and an average educational training of 14.8 years (SD = 1.4 years). All subjects were right-handed (Chapman and Chapman, 1987), and none had a history of neurological or psychiatric diseases, or of any developmental disorders or substance abuse (Campbell, 2000). Subjects were not reimbursed for their participation and written informed consent was obtained. The study had been done adhering to the conditions laid down in the Declaration of Helsinki.

2.2. Procedure

After the assessment of handedness and medical history, the first skin drawing test was administered. This required the writing of the letters A, B, and C (in this order) on a slip of paper (10.5 cm x 7.5 cm) to be held by participants with their left hand on one's front. It was stressed that handwriting quality would not be judged. In fact, it was only recorded whether the writing was left-to-right oriented or mirror-reversed. During the subsequent 20 to 30 minutes, subjects solved a computer task unrelated to the present context. They were then administered the somatosensory gap bisection task (see below), followed by a traditional line bisection task in which the midpoint of 12 lines displayed on a A4-sized sheet (lengths 130 mm, 175 mm and 235 mm, respectively) had to be marked with a pencil held in the right hand. The second skin drawing test, identical to the first in all respects, concluded testing.

2.3 Somatosensory gap bisection

Subjects were tested in a comfortable sitting positions with their eyes closed. During forehead testing, the examiner softly pressed two metallic styluses (diameter of tips 1 mm) to the skin of the subject's forehead. These were fixed to a ruler that, held in between the two styluses, guaranteed an equal and constant pressure at the two stimulation points. Three rulers were used, each with a different distance between the two styluses, i.e 50mm, 70mm and 90mm. Styluses protruded 20 mm from the two small-distance rulers and 40 mm from the long-distance ruler. The subject used a metallic rod (length 10 cm, diameter of tip 1 mm) to point to the subjective midpoint between the two felt stimuli with the right hand. There was no time constraint, but subjects were trained in a practice run to respond at a rate that allowed to keep the intertrial interval between 15 and 25 sec (Spidalieri & Sgolastra, 1997). Once the skin was touched by the response stylus, subjects were not allowed to reallocate its position, and the deviation from the actual midpoint between the two styluses was measured by the examiner to the nearest mm. To prevent the actual midpoint from being located at similar spots on the skin on consecutive trials and to avoid that it simply coincided with the head midline, a record sheet indicated where to place the ruler, i.e the left stylus had to be aligned with either the outer rim of the left eye, its inner rim, or a point that corresponded as closely as possible with the midpoint of the eye. Fourteen trials were thus administered, locations of the rulers and distances between the styluses alternating pseudorandomly (in an identical sequence for all subjects).

During gap bisections on the back of subjects' head, ruler locations were matched to those used during forehead testing by placing a paper ribbon tightly around the subject's head on which the eyes were drawn above the real eyes, reflecting an individual's eye size and distance between the eyes (Figure 2). By rotating the ribbon 180°, the examiner could apply an analogously randomized stimulation sequence (14 trials) on the back of the head. Response conditions were equal to those described for forehead testing. Half of the subjects of each gender group were tested first on the forehead, the other half first on the back of their head.

While physiological constrains for the pointing movement, tactile acuity, or skin properties (e.g. hairiness) are likely to differ between the front and the back of the head, we did not systematically address or correct for these potential confounds. The reason for this was, that we did not expect such mechanisms to bias the participants' judgments in any systematic way (e.g. always to the left, thus increasing a pseudo-neglect like behavior).

3. Results

3.1 Skin writing task

15 subjects (9 women) produced mirror writing in the skin-writing test on both occasions ("embodied eye"), 22 (10 women) consistently produced a regular writing ("disembodied eye"). The data of the three subjects with an inconsistent skin writing habit (2 subjects "disembodied" on first, "embodied" on second testing, a third one first "embodied" then "disembodied") were not analyzed.

3.2 Cutaneous gap bisection

Averaged over all gaps, the mean deviations from the midline were 3.54mm (SEM = 0.7) to the right on the front and 2.69mm (SEM = 1.0) to the left on the back, both of which were significantly different from zero as indicated by a one sample t-test (two-tailed, front: $t=4.99$, $p<0.001$, back $t=2.62$, $p=0.013$).

For the ANOVA, deviations were calculated as percentages of the respective gap width; positive values suggest a deviation towards the participant's right ear, negative towards the participant's left ear. We calculated an ANOVA with the between subject factor GROUP (dis/embodied eye group) and the within-factors LOCATION (forehead vs. back of head) and GAP WIDTH (50mm, 70mm, 99mm). This analysis produced a significant main effect of

LOCATION ($F(1,35)=44.32$, $p<0.001$) with positive values (i.e. a pseudoneglect as if seen from a disembodied perspective) in the front and negative values (i.e. a pseudoneglect as seen from an embodied perspective) in the back. It further revealed a main effect of GAP WIDTH ($F(1.14,35)=10.0$, $p=0.01$) for which Sidak post-hoc comparisons suggest a stronger leftwards deviation in the short as compared to the medium ($p=0.004$) and the long ($p=0.007$) gap width. For the interaction effects, the interaction of GAP WIDTH and LOCATION proved significant ($F(1.60,34)=4.26$, $p=0.026$) and so did the triple interaction of GROUP, GAP WITH and LOCATION ($F(1.60,34)=4.17$, $p=0.028$, corrected for lack of sphericity using a Greenhouse Geisser correction). Figure 1 shows this 3-way interaction. Posthoc t-test between participants (1-tailed) revealed a significant difference in the predicted direction between the disembodied and the embodied group only in the long gap width ($p=0.035$).

In order to investigate the relation between gap bisections on the back and on the front, a mean % deviation on the front and on the back were calculated and correlated using a Pearson correlation. The results show a highly significant negative correlation ($r=-0.44$, $p=0.007$).

3.3 Visual line bisection

Mean deviation in traditional line bisections was 0.53mm (SEM = 0.45) to the left of the objective midpoint for the whole group. A one sample t-test suggests no significant difference to zero ($t=1,18$, $p=0.25$).

4. Discussion

This study revealed two main findings. *First*, and as expected, the results show a systematic bias in a gap bisection task, which speaks for a pseudoneglect in the somatosensory system as it has previously been described for the visual system. *Second*, if the systematic deviation from the midpoint is taken as an index of a pseudoneglect, it suggest that participants generally spontaneously took a disembodied perspective during the gap bisection task on the forehead while they used an embodied perspective for gap bisection on the back of their head. This effect depended slightly but far less than expected on the spontaneous perspective taken during a graphesthesia task (writing letters on one's forehead).

4.1 The existence of a somatosensory pseudo-neglect

It seems fairly simple to point to the middle of a visually inspected line, or a haptically explored rod or even to bisect the gap between two points. Yet, in healthy, right-handed subjects, line bisections are slightly but consistently shifted towards the left of the objective midpoint.

Interpreted as a relative underestimation of the right side of space, this phenomenon was dubbed “pseudoneglect” by (Bowers & Heilman, 1980). A similar, albeit smaller effect was found for gap bisection (Bradshaw et al., 1986). This effect is commonly explained by a right hemisphere dominance in the orienting of spatial attention (e.g. Làdavas, Del Pesce, & Provinciali, 1989), but the exact causes are still poorly understood (Longo, Trippier, Vagnoni, & Lourenco, 2015). The present study was the first to test whether a comparable effect exists in the somatosensory domain when bisecting a spatial extension on one's own body. Previous related studies have tested the participant's ability to point to the trunk midline, and the majority of publications have described a leftward shift of the subjective meridian (e.g. Spidalieri & Sgolastra, 1999, but see e.g. 2001 for a failed replication). Importantly, these studies tested the midline pointing only on the front and never on the back of the participant's head. This might be problematic, given the fact that many participants seem to spontaneously take a disembodied perspective on their own body's front (e.g. Parsons, 1987). The present results suggest a clear leftward bias in the gap bisection task on the back, while the opposite was found for the front. Building on literature using the graphesthetic task (Stracke, 1947), the former finding (see 4.2 for the discussion of the latter) suggests that participants may take an embodied perspective when observing their back with their mind’s eye, hence they display a pseudoneglect. In analogy to explanations of pseudoneglect in the visual modality, this result could be explained by assuming a right-hemispheric dominance in spatial attention (e.g. Làdavas et al., 1989) that also comprises visual imagery, possibly automatically triggered by touch on the back of one’s body. In the visual domain, a right hemispheric dominance of near space processing might further strengthen the pseudoneglect, which is evidenced by various studies showing increased leftwards deviations with decreasing distance between the line and the observer (e.g. Longo et al., 2015). In this context, it should be noted, that in the current sample of participants we did not find a pseudoneglect in the classical visual line bisection task. While this could be due to methodological issues (e.g. less experimental trials in the visual task), it could also be speculated that the additional right-hemispheric dominance in body - and especially *own* body - processing (e.g. Frassinetti, Maini, Romualdi, Galante, & Avanzi, 2008) could have increased the pseudoneglect in the somatosensory as compared to the visual task. Such interpretation of our results might be somewhat in conflict with recent data suggesting a more accurate bisection of body parts compared to objects when presented as visual stimuli in peripersonal space (Bolognini, Casanova, Maravita, & Vallar, 2012; Sposito, Bolognini, Vallar, Posteraro, & Maravita, 2010). Yet, there are too many differences between those experimental setups and the one used here to directly compare the data. Further studies will have to systematically investigate visual as compared to somatosensory bisection of objects and body parts both in the front- and back-space and with various distances to the body.

4.2 Embodied perspective on one's back and disembodied perspective on one's front

Surprisingly, when asked to bisect a gap of two cutaneous stimuli on the front, participants consistently deviate to their right ear, which would suggest, that they either show a *left*-sided inattention from the embodied perspective or that they take a disembodied, third-person perspective on their forehead for solving the task and thus a pseudoneglect from that perspective. Albeit currently rather speculative, we judge the latter option as more plausible, as it is further strengthened by the fact that deviations on the back where highly negatively correlated with those on the front. This finding suggests that those participants showing a large pseudoneglect from an embodied perspective when solving the task on the back also show a large pseudoneglect when solving the task on the front from a disembodied perspective.

Previous studies using the graphesthesia task vary in the percentage of people using an embodied versus a disembodied perspective for judgments on the front: Most studies found a large majority of participants to spontaneously employ an embodied perspective (Corcoran, 1977; Duke, 1966; Stracke, 1947) while others described a slight predominance of a *dis*embodied perspective (e.g. Ferrè et al., 2014), yet the reason for the interindividual differences are argely unknown. Our data from the letter-writing task showed that about 60% of the participants used a disembodied perspective to solve the task. Against our hypothesis, however, participants who took a third person perspective in the skin drawing test did not generally report a stronger deviation towards the right ear in the gap bisection task (although our respective prediction was confirmed for longest gaps) than participants using an embodied perspective. This suggests that different mechanisms are involved in letter drawing (or letter recognition) and the bisection of experimenter-applied cutaneous distances. Importantly, the perspective spontaneously taken on one's own body depends not only on the individual but also strongly on the task and the situation (see also (Brugger, 2002) for a discussion on the perception on one's own body in clinical cases). While it could be expected that the gap bisection task, as a rather non-social task, would be less likely to trigger a disembodied perspective, our data rather suggest the opposite: they suggests that the gap bisection task on the front is generally solved from a third person perspective. Such spontaneous third person perspective taking (i.e., altercentric intrusion) has previously been found in other tasks, most prominently probably in studies looking at reaction times and error rates on perspective taking tasks when a third person with a different view-point is present or absent in a scene (e.g.

Kragh Nielsen, Slade, Levy, & Holmes, 2015). Yet, these results and their conclusions are still debated (see e.g. Cole et al., 2016). While we are confident that the gap-bisection task introduced here might importantly add to the literature on perspective taking and its neural and social determinants, future studies should more carefully address the influence of methodological detail. For example, the mere presence of an experimenter in front, who touches the participant, could have affected task performance (see Hass, 1984 for a discussion), as it has been demonstrated in similar visual task (e.g. Tversky & Hard, 2009).

To conclude, our new experimental paradigm suggests the presence of a tactile pseudoneglect on the surface of one's own body. Cutaneous gap bisections may help to close the gap between a "personal geography" (Corcoran, 1977) determined by bodily landmarks and the orientation and navigation in external, interpersonal space. Our skin, long recognized as a social organ (Morrison, Löken, & Olausson, 2009), may hold the key to expand current perspectives on perspective taking: automatic social and empathic perspective taking may depend more on attentional and sensory factors than hitherto assumed.

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Figure Captions

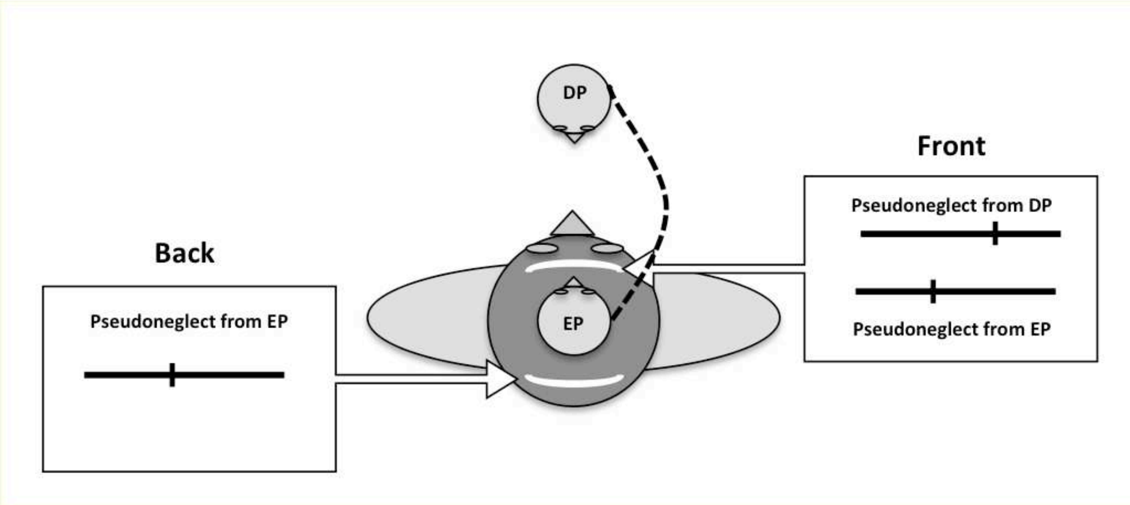

Figure 1: Schematic illustration of the different perspectives and the predicted deviation. Predicted deviation from the midline if a somatosensory pseudoneglect exists for the different perspectives on ones own body described in the literature. EP= embodied perspective, DP = disembodied perspective. While graphesthesia tasks on the back are consistently done from a EP perspective, those on the front might either be done from an EP or a DP.

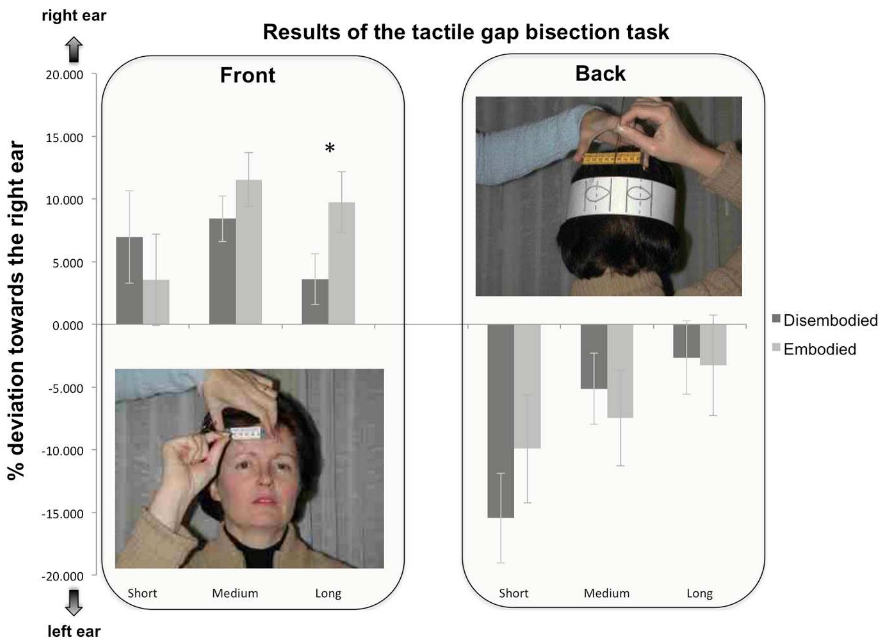

Figure 2: Results of the somatosensory gab bisection task. Mean displacements (with standard errors of the mean) towards the right ear in somatosensory gap bisections on the forehead (left) and on the back of one's head (right) for the three gap widths (short = 50mm,

medium = 70mm, long = 90mm). Dark gray are the participants with a disembodied, light gray with an embodied perspective according to the skin writing task.